

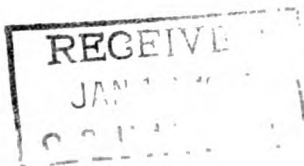
DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES

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THE INTERNATIONAL CONFERENCE
ON MINE SAFETY RESEARCH AT
BUXTON, ENGLAND, JULY, 1931



BY

GEORGE S. RICE

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AT BUXTON, ENGLAND, JULY, 1931¹

By G. S. Rice²

INTRODUCTION

To those concerned in attaining greater safety to life and incidentally to property in coal mining, the meeting of representatives of the national mine safety research organizations of the principal coal-producing countries, which was called by the Safety in Mines Research Board of Great Britain at its experimental station near Buxton, should have deep significance. It is notable, first, because it meant the friendly cooperation of countries not many years ago engaged on either side in the great World War; and second, because of the remarkable degree of agreement in the essential fundamental factors and methods of attaining greater safety in coal mines when it is considered that the questions were approached by different paths and that the applications dealt with widely differing natural conditions and national points of view.

Varying views, of course, were held as to the relative importance of certain factors, but the differences were of detail rather than of principle. When the meeting adjourned it was unanimously agreed that such meetings should be continued annually and that the greatest benefit was to be derived by close cooperation in the exchange of data.

Belgium, France, Germany, Great Britain, and the United States were represented by one or several members of the respective national research organization. It is of interest to note that this research work in Belgium, France, and Germany is supported directly by national organizations of mine operators or owners but placed under a scientist appointed by the respective Government, thus giving the work official standing. In Great Britain the work is carried on by a Government board, consisting of persons connected with the coal-mining industry or in mining research, appointed by the Secretary for Mines, to direct the work of research of the Mines Department. It does not, however, come under its inspection service. Its work is supported by a penny-a-ton tax on output of coal. In the United States the mine-safety research work is directly supported by the Federal Government.

In the four countries other than the United States, the findings of the research organizations may be applied in the mines but only after approval of the respective Government

1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used:
"Reprinted from U. S. Bureau of Mines Information Circular 6670."

A short abstract of the original draft was given at the meeting of the coal division of the American Institute of Mining and Metallurgical Engineers, October 9 and 10, 1931, at Bluefield, W. Va. The paper includes a summary of formal addresses presented at the conference, abstracts of the discussions, and pertinent information bearing on the subjects discussed. Since this paper was first prepared the complete papers presented at Buxton have been translated from the French and German, respectively, with edited discussion and have been recently published by the Safety in Mines Research Board as Paper 74, entitled "International Conference of Safety in Mines at Buxton, 1931," 1932, 67 pp. The British translations, addresses, and discussions in the foregoing have been freely drawn upon in checking the original manuscript.

2 - George S. Rice, chief mining engineer, U. S. Bureau of Mines, detailed to represent the bureau at the Buxton conference.

mine-inspection service, or ministry in charge of mining, but in the United States, as is well known, the findings of the Bureau of Mines can not be made mandatory by the Federal Government and may or may not be made compulsory by any one of the various State coal-mine inspection departments. The utilization of the bureau's recommendations is largely a matter of voluntary adoption by mining companies of those suggestions it favorably regards. It need hardly be pointed out what an immense advantage for safety it is when the mining regulations are the same throughout a country and are thoroughly enforced. As an example of what may be done: In Great Britain, since the safety research work was begun, first carried on by the mine owners themselves in 1908, enforcement of better regulations was demanded by the Mining Department, and as a result the accident rate has been reduced from 1.33 men killed annually in coal mining to 1.07 in 1930 per 1,000 men employed underground.

PITTSBURGH INTERNATIONAL CONFERENCE IN 1912

It is of interest to recall that the first international research station conference³ was held in Pittsburgh in 1912. It was called by the Bureau of Mines four years after the original Federal experiment station had been established there (1908) and shortly after its Experimental mine near Pittsburgh had been developed (1911) for testing. That conference, attended by delegates from the countries carrying on coal-mining research, was a splendid success, and another was to have been held in Belgium in August, 1914.

COOPERATION BETWEEN GREAT BRITAIN AND UNITED STATES IN 1923

Following the World War, research in the interest of safety in coal mining was gradually resumed in the various countries, and in 1923 negotiations were conducted between the British Safety in Mines Research Board and the United States Bureau of Mines which led to an official cooperation in mine safety research. This was consummated in the following year. The cooperation called for the interchange of research workers, of materials, of instruments for standardized testing, and of progress reports in cooperative problems.

The results have been singularly successful in establishing standards of comparison and have been stimulative to the respective staffs through the interchange of personnel. Valuable research has been carried on and publications issued thereon, also unnecessary duplication of work has been avoided. One side may be so equipped through having specialists on its staff as to be able to carry on some special work of value to both sides. Further confidence in a specific finding is given when the same result is obtained by both sides who may employ different ways of approaching the problem.

The Safety in Mines Research Board undertook, two years ago, a similar though more limited cooperation with the French experimental station at Montlucon. The favorable results of these two international cooperations led the board to call the international conference held July 11 to 16, 1931, at Buxton, England.

THE BUXTON (ENGLAND) INTERNATIONAL CONFERENCE

The delegates to the conference were greeted by Dr. R. V. Wheeler, director of research of the Safety in Mines Research Board, who had organized the conference.

The formal meeting was opened by Sir Edward Troup, K.C.B., chairman of the board, on July 11, who gave an official welcome and outlined the program. He said that while the program chiefly related to research in explosives, it would be desirable that other subjects be

3 - Rice, George S. (compiled) International Conference of Mine-Experiment Stations; Bull. 82, Bureau of Mines, 1914.

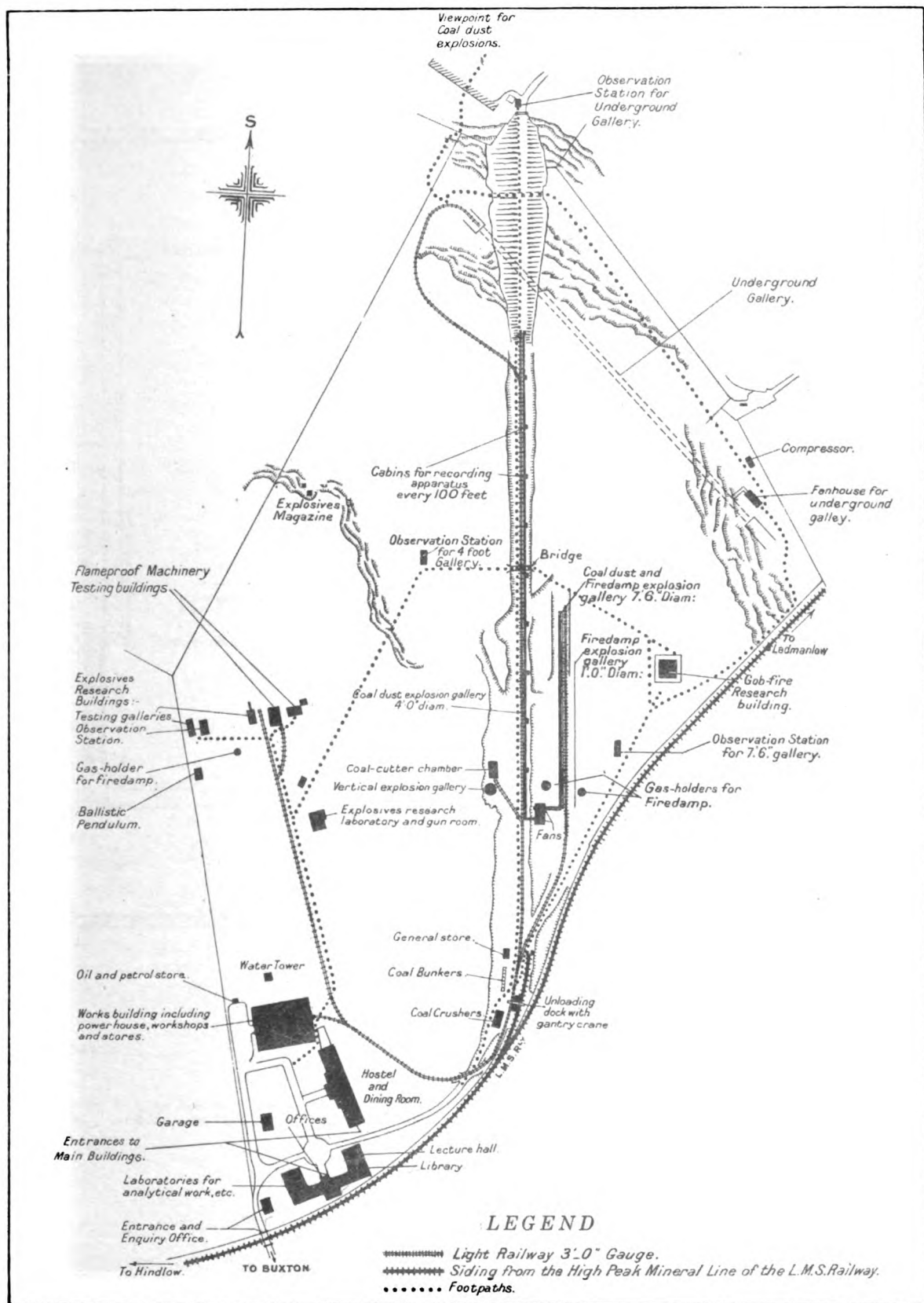


Figure 1.—Plan of Safety in Mines Research Station, Buxton

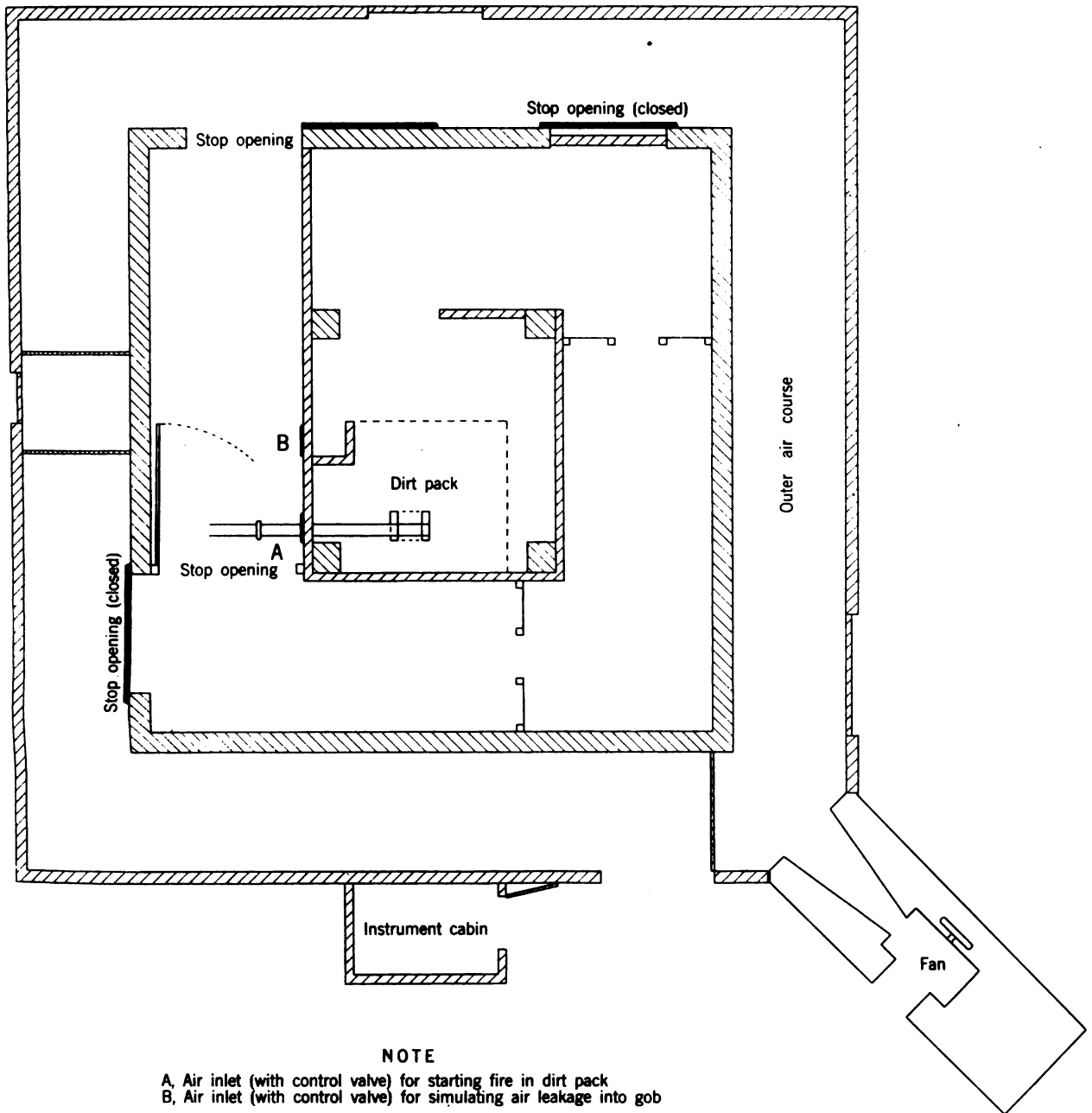


Figure 2.—Plan of gob-fire chamber as arranged for experiment 14

discussed, such as the essential safety requirements for flameproof enclosures for electrical mining apparatus, and accidents from falls of roof. He briefly referred to the existing co-operations in mine safety research as between Great Britain and the United States, Great Britain and France, and France with Belgium. In concluding he hoped that the delegates to the conference would see their way to formulating a proposal of continued interchange of information on safety research.

Replies made by Mr. Audibert of France, Dr. Beyling of Germany, Mr. Breyre of Belgium, and by the writer, expressed their pleasure at attending the conference and their personal desire to aid in the promotion of the proposed wider cooperation in research. After remarks by Wheeler on the details of the conference program a preliminary tour of the splendidly equipped station was made. The layout of the station is shown in Figure 1.

Weekly Demonstrations for Visiting Miners

On the following day, Sunday, the delegates were invited to attend one of the instructive "demonstrations" held each Sunday during the summer months for parties of miners and mining officials coming from one or another of the collieries or mining centers within reach by bus travel. Usually this means coming from the nearby Yorkshire coal field, but occasionally the men are brought by train from distant fields. The parties consist of from 50 to 100 men but sometimes are larger. On this occasion (July 12) a party of about 100 came on special busses from a Nottingham group of collieries.

Dust-explosion Demonstration in Underground Gallery

In accordance with the usual program for such visits, the miners were given a demonstration of a coal-dust explosion in an underground gallery or tunnel driven through a spur of a plateau. During a test it is closed at one end by a heavy steel portcullis door. The tunnel is about 800 feet in length, 8 feet wide, and 8 feet high, and is connected near the door end by a side drift to a fan. At present this underground gallery is not used for precise coal-dust and gas explosibility tests; these are conducted in an outside steel gallery 4 feet in diameter and 1,000 feet long, equipped with United States Bureau of Mines manometers. The tunnel is constructed through a spur of a high plateau on which the extensive research plant is placed. The tunnel has been driven through a limestone stratum which is much creviced and shattered. It is lined nearly all the way by either concrete or steel arching, but the lining is not tight and the tunnel is so very wet that it might be expected that coal-dust explosions could not be produced; however, just as in the Bruceton experimental mine, when in summer the humidity of the ventilating current normally is high and the walls and floor become wet (that is, if a drying system is not used), there is no difficulty in causing strong coal-dust explosions by coal-dust newly strewn along the passageway on its ribs, timbers, and floor.

Another part of the Sunday demonstration program at Buxton is to divide up the parties into groups of 15 or 20 persons, place each under a member of the staff, who conducts his group to each of the galleries and test chambers and explains its purpose.

Gob-Fire Testing Chamber

A test chamber that attracts general attention of mining men is one designed for the study of gob fires and their control. A plan of the chamber is shown in Figure 2. It has been definitely shown repeatedly by controlled tests that a gob fire will generate explosive gases, hydrogen and hydrocarbons, that under certain test-controlled conditions of admission

of air, simulating leakage through stoppings or walls, the gas-air mixture will ignite at the fire and cause severe explosions without the prior introduction of methane. Reports on this research and many others have been published by the Safety in Mines Research Board either as progress or final reports.

Ignition of Fire Damp by Frictional Sparks

An impressive test, which illustrates the necessity of frequent examination for gas while machine cutting, was demonstrated in a gallery by the ignition of methane in operating a mining-machine while its bits were cutting into pyritic balls or, in other tests, hard quartzitic sandstone of the kind which underlies some coal beds. Another test demonstrating the ignition of an air-methane mixture by frictional sparks was made in a box by striking with a hand-pick on a particular type of hard, sandy rock.

Possible Ignition of Fire Damp by Compression from Shot

The ignition of an air-methane mixture by adiabatic compression, such as might be caused by a blast in which the explosive gases are projected through a crevice to an opening containing a methane-air mixture is shown experimentally by suddenly compressing a methane-air mixture in a cylinder which automatically raises the temperature of the mixture sufficiently to ignite it; then the flame produced passes through a small hole in the cylinder head to another chamber containing a similar inflammable mixture, and ignites that.

Many other researches are carried on of a fundamental character; in fact, the British board is carrying on at the present time more kinds of fundamental research in coal-mine safety work than is being done in any other countries.

Lectures to Miners and Discussions

The miners' Sunday program includes taking up some practical mining question in a lecture hall. After a talk by a member of the staff, discussion follows in which the miners, as well as their officials, are urged to take part. This is not only educational to the miners but is of value to the staff of the board in obtaining the miners' point of view. The subject discussed, led by Major H. M. Hudspeth, at the meeting attended by members of the international conference, was on falls of roof and roof control by systematic timbering.

Roof Movement and Control Studies of the Board

The staff of the board is now studying the question of support of workings in different districts of the country, and, in the Durham, Northumberland, and Scottish fields, in conjunction therewith, testing is being carried on with dynamometer props and continuous recorders of subsidence of roof and rise of floor in the working places with the object of determining the best method of support in longwall faces and also in headings of bord and pillar workings. The dynamometer props being experimented with are of two kinds: The Wazau of German design employs a cylinder containing mercury, placed axially in the telescopic steel prop; under pressure the mercury is forced out through a hole of small diameter into a graduated receptacle. The relation of the amount of mercury displaced to roof pressure, is obtained by prior calibration in a hydraulic pressure testing machine. The second type, designed by Dr. A. Winstanley of the Safety in Mines Research Board staff, consists of a steel bar with enlarged ends. To avoid the effect of its rigidity on the roof stratum, it is cushioned at the top by a wood cap piece and under its foot by wood blocks. Punch marks

are made on the four quadrants, top and bottom, and strain gages of the ordinary type employed for determining compression and tension in metal structural pieces are used at regular intervals to determine the pressure produced by the roof and floor. Calibration of the props was obtained by prior testing in a hydraulic-pressure machine.⁴

The subsidence recorders are of the Safety in Mines Research Board design. They consist of a telescopic bar and cylinder with spiral spring to hold it firmly against the roof and floor. It is arranged to telescope under compression, and, through action of a lever arm, a style or lead traces a line of relative movement due to compression or convergence of roof and floor, on paper wrapped around a revolving drum actuated by clockwork, thus obtaining subsidence records with reference to definite times. Some of the recorders register data for a period of 24 hours and others for a week.⁵

These devices and methods of testing provide new ways of studying roof control and the design, strength, and intervals apart of roof supports such as pack walls, steel props, girders, and timbers. Although it is too early to give conclusive results, the writer's observation of this work in certain mines in Great Britain convinced him that these new methods of testing in mines will give information of great practical value to mining men.

PROGRAM OF THE INTERNATIONAL CONFERENCE

Although many kinds of coal-mine safety problems were discussed informally by the delegates to the conference in the course of visits to the different kinds of testing apparatus at the Buxton station and research laboratories of the board at Sheffield, the formal program during the meetings in the lecture hall at Buxton related principally to explosives of permitted or permissible type, their behavior under certain conditions, their hazard when used in gassy and dusty mines, and cognate matters.

Address by A. Breyre on Multiple Shot Firing - Classification of Mines in Belgium

A. Breyre, administrator-director of the National Institute of Mines, the research work of which is carried on near Frameries, Belgium, in an illustrated address advanced the idea that simultaneous firing of shots in a heading or working place is safer than firing one shot at a time and attempting to test for gas between shots. Belgian coal mines are divided into four groups as respects fire damp: Mines without fire damp; mines of the "first class," which are only slightly gassy; mines of the "second class," which are definitely gassy; and mines of the "third class," which are liable to instantaneous outbursts of gas. The effect of dustiness of a coal seam is superimposed on the classification of fire damp; coals containing less than 15 per cent of volatile combustible matter are considered to produce dust not dangerous, coals containing 15 to 22 per cent are considered to produce dangerous dusts, and dusts of coals with over 22 per cent are considered of very dangerous character. The presence of the dangerous dusts in a seam being worked may raise the classification of the mines on a fire damp basis to a higher or more dangerous class.

Simultaneous Shot Firing In Gassy And Outburst Mines

The Belgian regulations permit simultaneous shot firing in mines of the first class (slightly gassy) in shaft sinking, crosscutting, and development roads. In mines of the

4 - A dynamometer prop of similar type, a seamless steel pipe had been designed for testing roof pressure in headings in the Experimental mine of the Bureau of Mines and will be tried out in the near future.

5 - A duplicate recorder has been constructed by the Bureau of Mines for similar studies of convergence of roof and floor.

second class only one shot at a time may be fired, and external stemming (rock-dust) or a cartridge sheath (Lemaire's rock-dust sheath) must be used. Further, all shot firing in coal is forbidden in very gassy mines (class 2 and 3). There are, however, two exemptions from this regulation: Namely, in those anthracite seams under class 2, the coal of which is hard and the dust regarded as nonexplosive, and in certain mines (class 3) liable to instantaneous outbursts in which "volley" firing of shots to shatter the coal in the faces of certain workings is done to induce threatening outbursts. But volley firing is permitted only under the condition of firing from the surface or from protected or refuge plans or chambers when all men are out of the mine or affected district.⁶

Breyre described tests of multiple shot firing made by his predecessor, the late Mr. Lemaire, in the National Institute's Colfontaine gallery, a heading driven into rock in which 2 to 6 shots of permitted explosive were fired simultaneously in the respective test, into a firedamp-air mixture without producing its ignition. As a result Lemaire's opinion was that simultaneous shot firing presents no more danger than single shot firing.

Breyre made a series of tests in the institute's surface gallery, firing into fire damp and into coal-dust, without causing ignitions. He cited as confirmatory evidence that in two mines subject to instantaneous outbursts, between 1922 and 1931, 4,618 shots in 335 volleys had been fired, in one mine, 10 to 27 shots in a volley, and in the other mine, 3,181 shots with 6 to 30 shots in a volley had been fired without igniting gas, although the shots induced the occurrence of a number of gas outbursts.

As Breyre stated, these shattering shots fired in volleys are not directly comparable with normal shot firing in a heading; but they are suggestive as concerns the safety of multiple shot firing.

Breyre's Conclusions About Multiple Shot Firing and Requirements for Detonators

Breyre in his conclusions says:

- (a) Series connections of shots in a single circuit are strongly recommended.
- (b) Electric detonators must be carefully classified in respect to their resistance in ohms and in respect to those in which the same amount of heat will be dissipated in the same time.

In Belgium regulations require the manufacturer to class together all detonators of the same resistance and to mark the packets accordingly (for example, 1.4 to 1.5 ohms). This applies to low-tension detonators having a platinum bridge.

The majority of mines have a small apparatus for testing periodically the figures given by the manufacturer. One mine liable to gas outbursts and requiring a large number of shots in a volley specifies to the manufacturer that the resistance of the detonators does not vary by more than 0.02 ohm. With carefully selected detonators, misfires are very rare.

Of the few misfires that do occur which are chargeable to defective detonators not all are due to improper resistance, but exceptionally may result from humidity of the igniting

6 - The nature of instantaneous outbursts of gas which have occurred in certain mines in Lower Silesia, Germany, where the gas is carbon dioxide, and in certain mines in British Columbia, South Wales, France (Gard Basin), and Belgium where the gas is chiefly methane is described in a symposium on the subject given before the American Institute of Mining and Metallurgical Engineers. This is presented in papers entitled: Introductory Notes on Origin of Instantaneous Outbursts of Gas in Certain Coal Mines of Europe and Western Canada, by G. S. Rice; Instantaneous Outbursts of Carbon Dioxide in Coal Mines in Lower Silesia, Germany, by P.A.C. Wilson (Neurode, Germany), and discussions by various persons; Transactions of the Coal Division of the American Institute of Mining and Metallurgical Engineers, 1931, pp. 75-136.

material surrounding the bridge wire or to the detachment of the head of collodion which generally seals the socket of the detonator.

(c) Simultaneous shot firing necessitates careful examination of the face after each volley to detect possible misfires.

(d) The shot-firing device or unit (termed exploders in Great Britain) must be powerful; underground experience has shown that they rapidly lose some of their power in service. Breyre recommends as a general rule the application of a coefficient of 0.5 to the rating given by the manufacturers as regards the maximum number of shots the apparatus can fire simultaneously. The shot-firing device should be so designed that it can pass the current into the firing circuit only when the current has reached its full strength. If the current passed in the circuit initially was low and then increased there would be a possibility that the less resistant detonators would explode prematurely.⁷

In concluding Breyre remarked that he was under the impression that Great Britain and Belgium were the only countries not yet permitting simultaneous multiple shot firing. (The United States Bureau of Mines has not as yet recommended multiple shot firing in coal mines).

Discussion of Multiple Shot Firing Position of France

Audibert said not only was simultaneous shot firing permitted in France, but it was required. He felt that as far as ignition of fire damp was concerned simultaneous shot firing was no more hazardous than firing single shots.

In connection with the considerable delay that had been noted in the blast when firing a number of shots simultaneously, Taffanel had shown that it was impossible for any difference in the detonators to account for a long lapse of time. Audibert remarked that what he had to say referred only to French explosives and suggested that the apparent lag of detonation on firing a number of shots simultaneously may be caused by deflagration of one of the shots, which might be due to a gap between cartridges. In 27 years, however, French mines had only nine recorded instances of ignition of fire damp, from shot firing.

Position of Germany

Beyling said that in Germany all coal mines were considered to be gassy and all explosives that were used in the coal mines were tested for permissibility. He claimed that no explosion had occurred in German coal mines for many years which could be attributed solely to an explosive cartridge. Such explosions as had occurred in connection with their use were, for example, due to the use of aluminum-sheathed detonators. In only one such explosion was simultaneous shot firing in use and in his opinion the explosion would have occurred even if only one shot had been fired. As the result of his tests in the Hibernia experimental mine (Ruhr district) he was not inclined to the view that it was more dangerous to fire several shots than one, but rather that firing a number of shots simultaneously was safer than firing one shot at a time.

Effect of Size of Testing Gallery.— In testing work in galleries he agreed with Breyre that the safety factor of an explosive is reduced as the cross section of the gallery is made smaller but not in proportion to the reduction. In comparing Breyre's experiments in a gallery with conditions found in practice, he pointed out that the gas which may be ignited

7 - Subsequent to the conference, Breyre informed the writer that there were multiple shot firing devices manufactured in Austria which met the requirements of current strength and limited the duration of current to 0.03 second. Testing of these and other multiple shot firing devices is being undertaken by the U. S. Bureau of Mines at its Pittsburgh station.

in front of the shot hole is not pure fire damp but a mixture of fire damp and gaseous products of detonation.

Ignition Effect of Explosive Does Not Increase Beyond a Maximum Weight of Explosion.— In testing in the Hibernia experimental mine (near Dortmund) Beyling found that a series of shots with charges of 700 grams gave no ignitions, while another series with the same explosive with 600 grams gave an ignition on the fourth test and a series with charges of 500 grams gave an ignition almost every time. As a result of these observations the charge limits of explosives in the German test gallery are determined with charges between 400 and 500 grams in weight, as being the range in which the greatest danger exists. This supports the contention that it is not a pure fire damp mixture which may be ignited by an explosive (under the conditions of test), but when large charges are used a high concentration of the gaseous products of detonation is obtained in front of the shot hole and this probably is less inflammable than a methane-air mixture. He concluded, therefore, that within limits, the greater the charge the less is the liability of ignition.

(The writer of this paper suggests that this conclusion may not be valid for a shot in the open face of a mine working, but perhaps applies only to a gallery or heading of limited cross-sectional area).

Beyling did not consider that the misfires obtained in simultaneous shot-firing were of sufficient importance to be a reason for prohibiting the practice. He suggested that Breyre's specifications of range for resistance variations of detonators was narrow. This was not the requirement in Germany and he did not think that two detonators with exactly the same resistance would operate more reliably than those of which the resistance varied between, say, 1.4 and 1.5 ohms. He could not see the practical value of laying stress on precise resistance, such as mentioned by Breyre, — a tolerance allowed manufacturers of only 0.05 ohm, — particularly as the measurements are made in a laboratory, which he (Beyling) did not consider a final criterion. In practice, the solder of the bridge wire may absorb so much heat that the detonator will not fire, and there are factors inherent in use of the detonator that must be taken into consideration. In any event the detonator should always operate reliably, irrespective of small differences in resistance.

Beyling, turning to the question of the possibility of ignition of fire damp by sparks from a shot-firing unit (exploder), said he felt that it was more important to consider the liability that the detonator leads will be pulled out of the hole and make a spark on contact. The probability of this occurring is greater with one shot than with a series of shots and becomes progressively less as the number of shots is increased.

Rother (chief of the German Mine Safety Department, Berlin) agreed with the previous speakers as to the greater safety of multiple, simultaneous shot firing over single shot firing. He said that a practical view of the whole problem must be taken, and that ignition of fire damp might depend as much on other factors as the number of shots fired — for instance, the length of the shot hole as well as the length of the stemming. He did not believe that with multiple shot firing the roof would suffer if proper care was exercised.

Position of Great Britain

Wynne of the British Mining Department stated that there was an ever-present fear among miners that cartridges from misfires might be lost in the coal. He said, however, that the experiments of Breyre had demonstrated the value and utility of simultaneous shot firing.

Discussion About Safe Exploders.— Wynne asked whether an exploder were available which was incapable of igniting fire damp.

Breyre replied that he knew of no exploder incapable of igniting fire damp, other than a dry battery.

Audibert agreed that he knew of no inherently safe and efficient exploder, but thought that a greater measure of safety could be obtained by limiting the time during which the electric circuit was closed.

Allsop of the Safety in Mines Research Board staff described the construction of an exploder which had been designed and built at the Sheffield laboratory in which all inductance had been eliminated and in which the circuit was closed for a very brief period. This exploder was inherently safe. (It had not yet been officially approved by the Mines Department.)

Payman of the Safety in Mines Research Board, when called upon by Wheeler, said that in Great Britain the regulations are practically the same as in Belgium, but that the reasons for forbidding simultaneous shot firing were different - for one thing, the difficulty of apportioning the work of a series of shots with the increased risk of a blown-out shot. Personally, he did not believe that there was any danger of ignition from a blown-out shot. Secondly there was a fear that the shots might not go off together; one might be fired before another. Further, the present British regulations take account of the possibility that one shot may do so much work as to render undesirable another shot in close proximity.

As regards misfires with this present system of single shots, about 1 misfire occurs to 2,000 shots fired. Other questions raised are the effect on roof control and the fumes formed by many shots fired simultaneously. These objections of the mining men will have to be overcome to introduce simultaneous shot firing in Great Britain.

Position of United States

The writer of this paper when called upon to discuss Breyre's address remarked how valuable the studies of Breyre and those other persons entering into the discussion would be to coal-mining men in the United States, particularly in mines where they are faced with the question of shot firing in pitching coal beds, or in gassy mines where the roof conditions are bad.

The problem of multiple shot firing is under consideration by the Mine Safety Board of the United States Bureau of Mines, which makes recommendations to the director of the bureau on questions of mine safety policies. The bureau has no mandatory power over mines, but like the Safety in Mines Research Board publishes recommendations based on tests and research. These recommendations may or may not be adopted by the different State mining departments which have coal mining to deal with. In the case of approvals of mining machines, devices, and explosives for use in gassy and dusty mines, and which present ignition hazards, the permissible specifications are usually accepted by the mining departments of the principal coal-producing States and in many instances are voluntarily adopted by leading mine operators.

Establishment of United States Bureau of Mines Pittsburgh Mine Safety Testing Station in 1908 Recommendations of an International Committee. - When the work of the Bureau of Mines was first started in 1908, the late Joseph A. Holmes, first director, enlisted the help of those representatives of Great Britain, Belgium, Germany, and France in charge of mine safety research. It was not possible, however, at that time to obtain the help of J. Taffanel, then director of the Lievin station, France. But a commission consisting of A. Desborough of the Explosives Department of the Home Office of Great Britain, Victor Watteyne, Inspector General of Mines, Belgium, and Carl Meissner, Mining Councilor of Germany, visited the United States in 1908, and their recommendations were influential in formulating the methods of testing and use of explosives in gassy and dusty coal mines. This testing began at Pittsburgh in the fall of 1908.

Specifications of Permissibility of Explosives: Recommendation of Single Shot Firing.-

Among the specifications for permissibility of an explosive were that its (maximum) charge limit be $1\frac{1}{4}$ pounds, that the drill hole should be properly located, the charge stemmed with clay, and only one shot at a time prepared and fired after examination by safety lamp of the atmosphere in the working place had determined that no gas within the limits of detection by a flame safety lamp was present. The specifications requiring the use of detonators with electric shot firing, discharging but one shot at a time, were not added until later.

If shot firing was done electrically from the surface when all men were out of the mine, a method then and now required in coal mines in the State of Utah, the foregoing recommendation of firing one shot at a time was waived. Other recommendations were made by the international committee, but these strongly influenced the adoption of the single shot firing policy of the bureau.

Shot Firing from the Surface⁸.— In mines where shot firing from the surface has been done in the States of Utah, Colorado, Oklahoma, and Alabama, there were ignitions of fire damp, but it is concluded that these were due to one of the following reasons:

- (1) Use of a strong and high-voltage current up to 250 or 550 volts with the tendency to leakage at temporary connections.
- (2) Defective wiring of circuits and use of uninsulated wires.
- (3) Prolonged leaving on of current, or throwing in the firing switch again.

The use of current of too high a voltage seems unwise on account of the temporary nature of shot-firing lines in the workings parts of the mine. Hence in some mines employing the method, the voltage of the shot-firing lines has been reduced to 110 volts.

Defective shot-firing circuits are difficult to avoid completely in an extensive mine which is one objection to the system of firing all shots at one time from the surface.

Prolonged application of current and repeated closing of the shot-firing switch formerly were probably the most prolific sources of trouble in causing arcing of the electric leads brought in contact by the blasts. The condition has been remedied in some installations by use of a mechanical shot-firing switch which permits but one contact, of short duration.

The use of "delay-action" detonators, which have been employed in a few districts in multiple shot firing in coal mines, is very reprehensible, as the delayed shot may shoot into gas and dust produced by the first blasts. The Buxton conferees stated that they regarded their use as highly dangerous in coal mines.

The chief and great merit in firing from the surface is that if an explosion occurs no one is killed. Nevertheless the system for various reasons has not been extensively adopted; in fact, with the growth of mechanism and concentrated mining, its use has lessened except in Utah where it is required by State regulation.

Multiple Shot Firing by Shot Firers.— The system of multiple shot-firing in individual working places, using fuse fired by shot firers when all other men are out of the mine, is still extensively practiced in the mines of the Middle West but has not been much used in the Appalachian field where there is the largest production of coal. This system lessens the hazards of explosions to the larger number of men but increases the hazards to the shot firers because they usually are hurried and do not take time or have opportunity of seeing the charge or burden of individual shots. To remedy this, the shot firers in some mines charge and stem all shots as well as fire them, when all others are out of the mine, but many mining men regard this as impracticable and unnecessary if care is taken otherwise, especially if electric shot firing using permissible explosives is done by experienced certified foremen.

8 - The comments that follow were not officially presented but were discussed informally at different times with members of the conference.

Demand for Multiple Shot Firing.— In steeply pitching workings, especially in gassy mines, there is real need of multiple shot firing; and it is extensively practiced, although not in accordance with existing Bureau of Mines recommendations which many progressive operators wish to follow; hence, the consideration at this time by the bureau of whether a system of simultaneous multiple electric shot firing can be made safe. The need of such a system also is urged by operators who employ mechanization extensively. The bureau is therefore investigating the question which appears to involve standardization of detonators, the duration and strength of the current required, the securing of a suitable multiple shot firing device that will not ignite fire damp and other practical blasting considerations.

Address by E. Audibert on the Testing of Explosives for Permissibility

Audibert described methods of testing explosives for use in gassy and dusty mines by the French and other stations, the determination of charge limits, and the discrepancies found in these under the different methods of testing employed by the various testing stations. Under the French law of 1890, the permissibility of explosives was not determined under a schedule of gallery tests in the presence of gas and (or) coal-dust as in other countries, but was based on certain requirements of composition and calculated detonation temperature. The French regulation of 1911 does not reaffirm this doctrine but states that only those explosives prescribed by the Minister of Public Works can be used in gassy mines. No specifications are given in his official decree as to what determines the official approval or nonapproval of an explosive.

While admitting that gallery tests of explosives have been useful in demonstrating the need of substituting safer explosives for black powder and dynamite in coal mining, Audibert expressed the view that gallery tests are not altogether satisfactory. He said that they reasoned in France that the charge limits of permitted explosives relate to an entirely arbitrary set of conditions, and hence, logically, a set of conditions must be fixed which give the smallest charge limit. They were successively testing at the Montlucon gallery the value of the various factors that influence the charge limits.

Based on their research he suggested that the variable factors, apart from those of chemical composition of the explosives, and character of the gallery are: The position and character of the detonator, the length and diameter of shot hole, diameter of cartridge, density of charge, the distance separating the charge from the mouth of the hole, the length and character of stemming if used, and the degree of deformation of the shot hole at the time the test is made.

In concluding Audibert stated: The Experimental Station of the Comité Central des Houillères de France has tentatively fixed the relation which, in the absence of stemming, exists between the charge limit and the conditions of firing when the initiation is direct (detonator in the outer end of the charge) and the diameter of the cartridge is equal or nearly equal to the diameter of the shot hole. It is therefore sufficient in order completely to define his conditions of shot firing, to indicate the nature of the explosive, the value of its density, the diameter of the cartridge, the value of the weight of the charge, and the distance separating the priming point from the mouth of the shot hole.

The research carried out in this manner has led to the conclusion that, for each explosive and for each value of the diameter of the cartridge and density of loading, there is a "limiting value" for the charge which has the property, either in the presence of fire damp or of coal-dust, of not producing ignition when fired without stemming. There are,

however, for every explosive and for every charge density and diameter of cartridge, two values: The one when the shot is fired in the presence of fire damp and the other when the shot is fired in the presence of coal-dust - properties which customarily are wrongly attributed to the charge and termed "charge limit" (that is, the maximum value of the charge which does not produce ignition of fire damp and (or) coal-dust). Safety in mines would be considerably increased by standardizing experiments to determine these properties.

Discussion of Audibert's Address on Testing of Explosives

In opening the discussion, Wheeler complimented Audibert on the careful analysis that he had made of the factors influencing test conditions. He pointed out that the task of standardization of certain factors was simplified in France by the fact that only one diameter of cartridge and borehole was permitted and direct initiation by placing the detonator in the outer end of the charge was compulsory.

Beyling said Audibert had suggested valuable ideas to those testing the safety of explosives, but everyone realized the gap between conditions of test and actual conditions under which an explosive is used in a mine, and that this gap made it impossible for the gallery tests to give absolute results. No claim had ever been made in Germany that these tests were absolute, but a large number of repeated tests overcame to a great extent that disadvantage. In Germany it is the regular practice to retest explosives already in the permitted list to insure that the standard of safety is maintained. Nearly 28 years' experience in testing had led to progressive improvement. Beyling stated that since 1925 there had been five explosions in mines in Germany in which shot firing had been implicated. In three of these the exploder (shot-firing device) was to blame and in the other two the explosives were used in a manner forbidden by regulations.

Referring to the distinction between stemmed and unstemmed charges, Beyling said that 1/8 millisecond after detonation the flame and detonation phenomena have ceased to exist, a fact that makes it unreasonable to suppose that ignition of fire damp is due directly to these factors. On the other hand, the hot gaseous products of detonation persist for a long period and may play some part in the ignition. He considered it impossible that a stemmed shot could be more dangerous than an unstemmed one, and upon this view was based his policy of carrying out tests with unstemmed shots as being the more dangerous.

Audibert said in reply he did not mean to suggest that the methods of testing explosives in other countries were unreliable, but he desired to present some new aspects of an old problem.

Beyling asked if Audibert considered the French explosives not sufficiently safe when judged by his standard; and also, would German and Belgian permitted explosives be found dangerous if fired under Audibert's conditions? Audibert replied that the majority would not be found unsafe, but that his principal aim was to find safer explosives.

Address by E. Beyling on Investigation of the Igniting Power of Explosives

Beyling described the successive steps that had been used in testing the permissibility of coal-mining explosives in Germany. For many years steel mortars and galleries of various sizes had been used, and while these had been valuable in differentiating between safe and unsafe explosives, it was desirable to obtain more fundamental information as to the cause and conditions attending ignition of gas and coal-dust by explosives. Accordingly, the

experimental mine⁹ at Gelsenkirchen (beginning in 1928) had been utilized to study the factors.

Previously in surface galleries at Dortmund and elsewhere Beyling and his associates had determined the length and duration of flame from explosives, its velocity, temperature, and products of detonation in connection with approving explosives for use in gassy mines. Now they were endeavoring, in the Gelsenkirchen mine, to determine what factors affect ignition. The explosive is fired in bore holes in a strong sandstone hanging wall. In certain of the tests the explosive is fired into a body of fire damp confined by diaphragms. Coal-dust had not yet been used.

One line of inquiry was to determine the size of flame from permitted explosives in blown-out shots. In this they studied the effect of the following factors: Amount of the charge, depth of the borehole, length of the free space, diameter of the cartridge, diameter of borehole, position of detonator in the charge, type of rock in which the borehole was placed, and the effect of various methods of stemming and no stemming. The principal results obtained were as follows:

(1) With a shot hole of constant depth and with the detonator in the same relative position in the charge, the flame of safety explosives decreases with an increase in weight of charge.

(2) With a charge of constant weight, the flame increases with an increase in the free space in the shot hole between the charge and mouth of the hole - that is, with increased depth of hole.

(3) With a constant free space the size of the flame is independent of the depth of the shot hole, provided that the charge is at the bottom of the hole. These results only apply to direct initiation with the detonator at the front, or to intermediate initiation; which is much favored in the Ruhr.

(4) The further the initiating charge or primer is situated within the charge - hence, the greater the number of cartridges between the detonator and the mouth of the hole - the greater is the flame produced. The largest flame was obtained with inverse initiation, when the detonator is situated at the bottom of the shot hole.

Another series of tests with safety explosives only was made in one of two chambers excavated in the rock in the lowest level of the mine, one chamber 4 square meters (43 sq. ft.) and the other 2 square meters (21.5 sq. ft.) in cross section. The difference in cross section was found to have no appreciable effect on ignition of fire damp and the narrow chamber was principally used.

The most important result obtained was that no safety explosives tested ignited fire damp when the detonator was inserted in the shot hole last - that is, with direct initiation. On the other hand fire damp was ignited when the detonator was situated in next to the last or outer cartridge (intermediate initiation) and also when it was in the first cartridge inserted in the hole (inverse initiation). This result appeared to confirm their prior supposition that the greater the size of the flame the greater the tendency to ignite fire damp;

9 - The experimental mine at Gelsenkirchen, Ruhr, Germany, was formerly the Hibernia mine. It is an old commercial mine which was started about the middle of the last century and abandoned as unprofitable in 1925. The coal beds are numerous but generally thin, and the upper more regular beds are largely worked out within the limits of the property. The lower coal beds are much crumpled and irregular. The hoisting shaft reaches a depth of about 3,000 feet. The 12 level - the lowest at a depth of about 2,920 feet - is a cross-measure drift largely in strong sandstone, and is the level in which the tests of explosives have been conducted. The mine was taken over in 1928 for experimental purposes jointly by the Ruhr Syndicate, the miner's association, and the Prussian Government; the research work is under the direction of Dr. Beyling. Some tests on explosives were observed by the writer in 1928. A series of annual reports has been made by Beyling and his associates.

for as he had previously stated in the flame experiments, they found that the flame increases with the increase of depth of the primer within the charge.

Fire damp was not invariably ignited when initiation was intermediate or inverse. In these tests contrary to the flame experiments, the free space in the shot hole, which had so marked an influence on the size of flame, had none in these tests. A shot with a small or no free span gave ignition, while the same explosive gave no ignition with a larger free space.

On comparing the results obtained with shots fired from holes of the same depth, it was found that the probability of an ignition increases as the charge is increased in spite of a reduction in the size of the flame. Yet he remarks that with the highest charges of 10 cartridges no ignitions were obtained, and with 8 cartridges nonignitions were far more numerous than ignitions. He added that this series of tests were not in accord with earlier tests and seem to indicate that the flame of safety explosives is not a determining factor of their relative safety.

Testing for Ignition of Fire Damp by its Compression Produced by a Blast

Beyling said that in searching for other causes of ignition they undertook to determine whether sudden compression of the fire damp in front of a blown-out shot might cause ignition. Lead plate disks were hung in front of the hole at varying distances so that the shot impinged on the center and then measured the deformation; however, the comparative measurements were so inconsistent that no satisfactory conclusion could be drawn, although there was a marked drop in deformation with distance from the mouth of the hole. At a distance of 1.50 meters (5 feet), for instance, the lead disks were so slightly deformed, even with large charges, that ignition was not likely.

Ejection of Hot Particles from Explosive

In the lead-plate tests an important observation was made that there was found after a shot a thick incrustation of undecomposed explosives on the face of the plate. Investigators in other countries, particularly Audibert, have thought ignition of fire damp might be caused by solid particles of explosive ejected from a shot hole, or to the reaction of inflammable gases from the explosive undergoing combustion outside of this hole. To determine this, shots were fired into pure oxygen gas and flame photographs were made. These showed a number of fine bright lines, which are undoubtedly due to the burning solid particles of explosive ejected from the borehole.

Confirmatory experiments to demonstrate that solid particles, either burning or in a hot state, are ejected was made by filling toy balloons with a mixture of $1/3$ methane and $2/3$ oxygen and suspended in front of the shot hole. These were ignited when three cartridges of Wetter-detonit B (a permissible explosive) were fired with a free space 22 centimeters (9 inches) long when placed within 2.75 meters (9 feet) from the shot hole. With five cartridges the distance was increased to 3.75 meters (12 feet). Neither the flame nor necessary compression effect extended to this distance. An additional proof that the flame was not responsible for ignition in these tests was indicated by a test in which the flame of an unauthorized (nonpermissible) explosive partly surrounded a balloon without causing its ignition, as shown by a photograph which Beyling exhibited.

To indicate that neither flame nor compression was responsible under the condition of the tests, an iron plate with seven small holes was suspended between the shot hole and the balloon; then in spite of the protective plate the balloon was ignited.

Detonation of an Explosive in a Glass Tube

To obtain some insight into the mechanism of detonation, some cartridges were inclosed in glass tubes and fired. The internal diameter of these tubes was equal to the standard diameter, $1\frac{1}{4}$ inches, of the shot holes in rock.

By photographing they were able to study the development of the reaction. The detonation was so rapid that the glass tube was only destroyed after the luminous phenomena had ceased. The glass tubes were 30, 36, and 54 inches long, respectively, and were closed at one end, with a clay plug 2 inches long. The bright luminosity of the detonator fuse head is clearly seen in the photographs; a dark space appears immediately above the charge in the free space. The nonluminosity of this part of the free space was surprising, and although several theories as to the chemical reactions were given by Beyling, he comments that it is difficult to explain. Flame phenomena above the charge are obtained only under one condition - namely, when stemming tightly seals off the free space. Rock-dust in a paper tube above the explosive in the glass tube produced the same phenomena as an unstemmed shot; that is, no luminosity was above the cartridge. In contrast a cartridge was freely suspended without enclosure and fired. The photograph Beyling exhibited shows how much fainter is the luminous record than when the cartridge is enclosed in a glass tube.

To further obtain an insight into the conditions of detonation in a glass tube, a flame-speed camera with a powerful photographic lens was used which focussed on a rapidly rotating film. This had a speed of 40 meters (132 feet) per second. It was found that the detonation wave travels through the charge with a velocity of about 3,000 meters (9,900 feet) per second, while the flame in the free space moves initially at a speed of about 1,800 meters (5,900 feet) and later of about 1,400 meters (4,600 feet) per second.

Discussion of Beyling's Paper

The writer, who was asked by the chairman, R. V. Wheeler, to open the discussion, said that it was very difficult for him to contribute anything but congratulations to Beyling on his masterly paper. He had been down in the Hibernia experimental mine in 1928 and observed some of Beyling's early tests of explosives fired in holes in hard sandstone. There were several points in Beyling's address that he had not understood. For example, the determination of pressure by impact of the pressure wave on a suspended lead disk. He wondered whether it was safe to reason from its degree of distortion the relative strength of the impact at different distances from the shot hole. Did not the time of producing physical effects in causing distortion, affect the comparative results? He thought that the piezo-electrical gage they had just seen at the Buxton Research Station might be a valuable aid in contributing to the study of shock waves from explosives through air by obtaining time records in connection with impacts.

He also asked if repeated shots in a blast hole in rock did not cause enlargement that might affect results when using a large quantity, say 800 grams, as compared with a lesser quantity of explosive.

Beyling, replying to the first question, said he considered the suggestion of making a time record of the impact of a pressure wave was good, but the experimental difficulties would be great. He had wanted to determine whether the pressure is increased in front of the shot hole and whether there is any connection between the ignition of fire damp and a sudden high pressure as produced by a blown-out shot, and he had tried to determine this by the simplest methods available.

As concerns the enlargement of the borehole, Beyling said that in his flame experiments 10 to 15 shots were fired in successive tests in the same hole and after each test the hole

was carefully measured and examined as to diameter and roughness. Appreciable variation in most instances was not noted. Different results naturally would be obtained in shale or coal.

Wheeler said that Rice's criticism of the use of lead disk to determine pressures because of the time factor should be considered.

Beyling replied that he realized that the lead plate was not an accurate method of measuring the pressure. Although the time factor was not considered, he thought the experiments could be regarded as indicating relative pressures in front of the borehole.

Breyre remarked that from Beyling's experiments, it would appear that the flame was not particularly important in the ignition of fire damp and that pressure also appeared to have little influence. It therefore remained to find out the culprit. He asked whether Beyling could give any idea as to what magnitude of pressure was indicated by a given deformation of the lead disk. He also wished Beyling to amplify his remarks concerning ignition by cartridges freely suspended.

Beyling said he did not preclude the possibilities of ignition of fire damp by the flame or by the compression due to a blown-out shot, but intended to convey the meaning that ignitions could be obtained which were not attributable to either of these causes. Regarding calibrating the lead disks, this had been considered, but it was regarded as an additional complication which for the experiments undertaken had not been thought necessary.

Audibert agreed with the suggestion made by Beyling that the detonation of an explosion takes place in two phases, the first being the travel of the explosion wave and the second the combustion of the gases. He did not believe that combustion is necessarily complete in the detonation wave; in fact, the experiment that he had carried on at Montlucon had definitely proved that it was not so. Beyling had gone further and said that, not only is combustion incomplete, but that certain portions of the explosive itself are not touched and remain behind the explosion wave. He suggested that this could be shown by calculation, that when a certain quantity of explosive burns, a given volume of gas should be formed, whereas the volume actually formed is much less.

With respect to photographs of freely suspended cartridges, they had succeeded at Montlucon in photographing the discharge of cartridges 100 to 200 grams but had shown that the effect on the photographic plate was exactly the same whether the explosive was one which would ignite fire damp or one which would not.

The writer asked what Beyling's conclusions were with regard to the part played by hot gases. He suggested that in Beyling's results, when he showed that certain large flames were combustion was more complete in one instance with rapid cooling due to the expansion than in the other. Furthermore, would not the temperature of the gases immediately beyond the end of visible flame be sufficient to ignite fire damp.

Beyling replied that Rice's suggestions were very interesting. His own experience was that the flame was rarely the cause of ignition. (This had reference to the flame of a permissible explosive).

Wheeler in closing the discussion said he had only one question to ask Beyling and that was, what is "flame." Were the pictures on his photographic plates necessarily of flame.

Beyling said that he no more knew what flame was than Wheeler did, and he could only assume that the luminous image shown on the photographic film was of flame.

Address by W. Payman on the Application of Schlieren Photography in Researches on Explosives

Payman said he had not prepared a formal paper because much of the work he was going to describe had been published or was in the course of publication. After briefly describing

the general methods of testing explosives at the Buxton station, he said as his address would to a large extent supplement Beyling's he would quote two of his remarks: First, they could not hope to have many further improvements in the safety of explosives until they were able to say what it is that causes the ignition of fire damp, and why an explosive sometimes does and sometimes does not ignite fire damp. Secondly, Beyling had shown that ignition of fire damp could be obtained when any one of the many and varied possible causes was absent. He (Payman) would add this observation, that any of the suggested causes of ignition - flame, hot gases, compression, solid particles - might cause the ignition of fire damp, but that no particular one is a necessary cause of ignition.

At Buxton they were trying by a photographic method to trace each of the effects obtained when an explosive is fired. They were not content to follow one single effect because they knew that each of them might assist another. Thus a pressure wave may pass through a gas mixture and heat it. It may not heat it sufficiently to ignite the gas, but it makes the task of ignition by flame, hot gases, or solid particles easier when they in turn come in contact with the gas mixture. They were also trying to follow the course of the process.

Payman described and illustrated with lantern slides different parts of the research work on explosives being carried on at the Buxton station and stated that present views of the staff were given in a publication just issued by the Safety in Mines Research Board, which was distributed to members of the conference in advance form.¹⁰

Payman then briefly described the research by the Schlieren method of the ignition of fire damp by explosives. This method had been developed at the Buxton station, and recently, under the cooperative agreement for research between the board and the United States Bureau of Mines, had been carried on further at the latter's explosives testing station near Bruce-ton, Pa. A Schlieren apparatus had been installed there by him and W.C.F. Shepherd of the board's staff. The latter had been detailed for that work for a period of 17 months and had just returned to England. Shepherd had been able to take several interesting series of photographs illustrating fire damp-air mixtures ignited by explosives.

The Schlieren method employs a concave metal mirror. A beam of light thrown on it is reflected as a converging beam, the beam is refracted by waves of atmospheric disturbance, such as produced by shock waves, flame, etc., from the explosives under test, and the effects are recorded on a high-speed photographic film.¹¹

Discussion of Various Mine Safety Matters

The program of the conference, as originally planned under the auspices of the Safety in Mines Research Board, related wholly to explosives, but at the suggestion of Sir Edward Troup other subjects were discussed informally on the last day of the conference (July 16). Among the problems briefly discussed were (a) the application of stone-dust (rock-dust) for the prevention of coal-dust explosions and (b) the testing of flameproof mining electrical apparatus. It was decided to defer detailed consideration of the problem of coal-dust explosions, including such matters as the use of stone-dust barriers and the most suitable kinds of stone-dusts to use, both for barriers and for general distribution on mine roadways, until another conference, the subjects being too large to deal with during the time remaining. However, the subject of testing the physical condition of stone-dust was briefly discussed.

10 - Grimshaw, H. C., and Payman, W., The Ignition of Fire Damp by Coal-Mining Explosives; Gallery Experiments: Safety in Mines Research Board, Paper 69, 1931, 45 pp.

11 - Shepherd, W.C.F., The Ignition of Fire Damp by Explosives. A Study of the Process of Ignition: Bull. 354, Bureau of Mines, 1932, 89 pp.

Testing the Tendency of Rock-Dusts to Absorb Moisture and to Cake

The problem involved in the tendency of rock-dusts to absorb moisture and to cake had arisen more or less acutely in Great Britain, Germany, and the United States. In some mines or in parts of mines where at times the mine air is humid or supersaturated, there is a tendency for the rock-dust distributed in the mine passages or in rock-dust barriers to cake and thus not be effective to raise as a dust cloud when an explosion occurs.

In England the question had come up in connection with the Haig Pit (Whitehaven) explosion disaster in the previous winter, and has frequently arisen in coal mines of the United States in the summer time because of the moistening of rock-dust by humid intake air and also in mines where watering is required at the mine faces, as in Utah. This condition also occurs in German mines and has been a matter of testing by Beyling. He subjects rock-dust samples to exposure in mine air for a certain period, and then uses the simple method of blowing a sample held on the palm of one's hand and estimates the relative amount dispersed.

At the Sheffield laboratory (England) a method of dispersal of a stone-dust sample by a suddenly applied jet of air has been tried; also other methods are being tested.

The United States Bureau of Mines has experimented with moistened rock-dust in various ways; tests have been made of the relative absorption of water by samples in tubes standing in water, the relative hardness of the caked dust as determined in a coke-crushing device, and the relative dispersibility of a rock-dust sample after having been spread for some weeks or months in the Bruceton Experimental mine.

The discussion by Wheeler, Beyling, Audibert, and the writer indicates that the problem had several phases: (1) The greater susceptibility of some rock or stone dusts than others to absorb moisture, (2) a difference in the hardness of caking when moistened, (3) a difference in the dispersability of rock-dusts by air waves or by blasts, of an explosion, when these dusts have been previously wet and then dried by the air currents.

It was agreed that none of the empiric methods now employed were satisfactory and it might well be a problem for an international cooperative study to develop test methods that might be standardized and capable of being employed quickly and conveniently by mining companies for the selection of a rock-dust least affected by humidity for use in their mines.

Testing of Mining Electrical Apparatus

As regards mining electrical apparatus, it was agreed by the conferees that it should be possible to draw up a unified code of structural requirements if not of tests, and that steps should be taken to prepare such a code for consideration.

PLAN OF INTERNATIONAL COOPERATION ON SAFETY IN MINES RESEARCH

The final important decision of the conference was that arrangements for a general international cooperation on safety in mines research should be made on the lines suggested by Sir Edward Troup, and the following proposals were adopted by the delegates, subject to ratification by the organizations concerned:

- (1) The arrangements will only relate to health and safety in coal mines.
- (2) The general arrangements shall be as between the directors of the respective research stations.
- (3) Cooperation will be effected principally by mutual periodic interchange of progress reports on programs of experimental work on health and safety in coal mines undertaken by the research stations.

(4) Such progress reports will be brief, but can be supplemented, if desired, by detailed reports on individual problems.

(5) If convenient, the cooperation will provide for the interchange of personnel, or the allocation of a member of the staff of one research station for work at another; and for the loan of apparatus and the supply of materials.

(6) An important feature of the cooperation to be aimed at, if possible, will be the production of agreed reports on matters of outstanding interest, with all the directors of research as joint authors.

(7) Periodic meetings of the directors of research shall be arranged at each research station in rotation.

On Friday, July 17, the Safety in Mines Research Laboratories at Sheffield were visited, and the conference then dispersed.

INTERNATIONAL INTERCHANGE OF REPORTS AND INFORMATION

Following the Buxton conference informal negotiations were entered into between the directors of the mine safety research work of Great Britain, France, Belgium, and Germany and the director of the United States Bureau of Mines, with reference to interchange of information, this for the present to involve only an exchange of confidential quarterly reports and brief progress reports of different pieces of mine safety and health research.

This proposal was agreed to by the respective directors, and the plan has been operative since January 1, 1932.

Such interchange is of undoubted value; often a specific research may not reach maturity and the findings be not sufficiently assured to permit publication for several years, if at all, or the research may even fail in the results hoped for by the investigator; yet the progress reports on that problem and the data obtained may be of great value to other investigators and may prevent needless experimentation by another station which might otherwise try the same procedure. Unnecessary duplication of work is avoided and money is saved to the respective organizations. Also if the same conclusions on some problem are reached by different ways of approach by two or more of the research stations, the agreement in results unquestionably gives added confidence in making specific recommendations to mining men concerning safety in their mines, and this is manifestly of importance to the whole coal mining industry. Already there have been a number of such instances of agreement in findings obtained through the British-American cooperation in mine safety research.